Question	Evidence	1-4 marks	5-6 marks	7-8 marks
ONE (a)	The reading will be zero. Across each cell the voltage rise (1 volt) must be equal to the voltage drop (*I* . *R*), so the total voltage change across each circuit element is zero.	Thorough understanding of these applications of physics. OR Partially correct mathematical solution to the given problems. AND / OR Partial understanding of these applications of physics.	(Partially) correct mathematical solution to the given problems. AND / OR Reasonably thorough understanding of these applications of physics.	Correct mathematical solution to the given problems. AND Thorough understanding of these applications of physics.
(b)(i)	The circuit is symmetrical. Equal sized currents must flow along the identical paths AB and AD. This means that the voltage drops across resistors AB and AD will be the same and so the potential at B and D will be the same.			
(b)(ii)	DO and BO do not have any current through them so do not contribute to the resistance. This leaves 3 parallel branches, each of resistance 2*r*. The total will be 2*r* / 3 Ω.			

Question	Evidence	1-4 marks	5-6 marks	7-8 marks
2(a)(i)	Kirchhoff's Potential Difference Law is a statement of the conservation of energy - in any closed loop the energy lost by circulating charges must equal the energy gained, as they complete the loop with same energy level that they started with. Kirchhoff's Current Law is a statement of the conservation of charge. Since there is no way for charge to be accumulated at a junction, the amount of charge leaving must equal the amount of charge arriving.	Partially correct mathematical solution to the given problems. AND / OR Partial discussion of the underlying physics of this application.	(Partially) correct mathematical solution to the given problems. AND Reasonably thorough discussion of the underlying physics of this application.	Thorough discussion of the underlying physics of this application. AND Correct mathematical solution to the given problems.
(a)(ii)	Use loop law to calculate current in the 4 ohm resistor $24 = 1 \times 12 + 4 \times i_1$ gives $i_1 = 3$ A and current in 8 ohm = 2 A.			
(b)(i)	The voltage across both resistors will start at 12 V when the switch is closed. Since the 1μF capacitor will charge quickly (τ = 1/1000 s), the voltage across the 1 kΩ resistor will fall and become effectively zero after 5/1000s. The mF capacitor with τ = 10s will charge slowly and so the voltage across the 10kΩ resistor will fall, but take 50 s to reach effective zero.			
(b)(ii)	After 10 s The 1 μF is charged to 12V. The 1000μF is only charged to $12 \times 0.63 =$ 7.56 V. When the battery is removed the capacitor voltages will equalise with a flow of charge from the 1 μF to the 1000 μF. The voltage of the 1μF will fall and that of the 1000 μF will rise. Initial current is given by Voltage difference / Resistance It is $\frac{4.44}{11\,\text{k}} = 0.403$ mA Total charge must remain constant so $Q_T = Q_1 + Q_{1000}$ $= 10^{-6} \times 12 + 10^{-3} \times 7.56$ $= 7.572 \times 10^{-3}$ C Total capacitance = $C_1 + C_2 = 1001 \times 10^{-6}$ F Final voltage of capacitors = Q / C = 7.572 / 1.001 = 7.56(4) V			

3(a)		Each bulb will have 12 V across it due to symmetry – given that this is the operating voltage of each bulb the resistances can be calculated by using R = V^2/P (the 20W bulbs have resistance = 7.2 ohms and the 40 W bulbs have resistance = 3.6 ohms). The majority of the current will take the path of least resistance so current will go from b to a. $I_1 \text{(top left hand branch)} = \frac{12}{7.2}$ and $I_2 \text{(bottom left hand branch)} = \frac{12}{3.6}$ $I_{ba} = -I_1 + I_2 = 1.67\text{ A}$	2
b)	1 mark for L_1 brighter and L_2 dimmer.	When switch S_2 is opened the same current exists in L_1 and L_2. The resistance of L_2 is unknown as we do not know the V-I characteristics of the bulb, but we can assume the value of the $L_2 < L_1$. This means L_1 has more voltage across it and therefore an increased current and brightness (it may blow). This then means that L_2 has less voltage than before and therefore less current so will be dimmer.	2
c)		We would need the V-I characteristics. Essentially its resistance values for all V and I values.	2

<table>
<tr><th>Q</th><th>Evidence</th><th>1–4
Below Schol</th><th>5–6
Scholarship</th><th>7–8
Outstanding</th></tr>
<tr><td>FOUR
(a)</td><td>$F_g = \dfrac{6.67\times10^{-11}\times9.11\times10^{-31}\times9.11\times10^{-31}}{R^2}$
$F_e = \dfrac{8.98\times10^{9}\times1.60\times10^{-19}\times1.60\times10^{-19}}{R^2}$
$\dfrac{F_g}{F_e} = 2.40\times10^{-43}$</td><td rowspan="4">Thorough understanding of these applications of physics.

OR

Partially correct mathematical solution to the given problems.

AND / OR

Partial understanding of these applications of physics.</td><td rowspan="4">(Partially) correct mathematical solution to the given problems.

AND / OR

Reasonably thorough understanding of these applications of physics.</td><td rowspan="4">Correct mathematical solution to the given problems.

AND

Thorough understanding of these applications of physics.</td></tr>
<tr><td>(b)</td><td>Two in parallel (capacitor and inductor), one in series (resistor).
Evidence:
Finite current at a zero and high frequency implies resistor in series.
Can’t have the capacitor in series (at low frequency – current would be zero).
Can’t have inductor in series (at high frequency – current would be zero).
Zero current at finite frequency implies infinite impedance – this can happen with parallel branch containing an inductor and a capacitor.</td></tr>
<tr><td>(c)</td><td>Take voltage to be V
$I_4 = \dfrac{V}{r+4}$
$I_1 = \dfrac{V}{r+1}$
$I^2R = 16 = \dfrac{4V^2}{(r+4)^2} = \dfrac{V^2}{(r+1)^2}$
$V^2 = 16(r^2+2r+1)$ and
$V^2 = 4(r^2+8r+16)$
$r^2+8r+16 = 4r^2+8r+4$
$3r^2 = 12$
$r = 2\ \Omega$
$V^2 = 144$
$V = 12$ volts</td></tr>
<tr><td>(d)</td><td>The electron associated with a single proton (forming a hydrogen atom) has a restricted set of possible energy values. We say the potential energy held by the electron is quantised because when the electron changes from large PE to less PE, the energy change is released as an electromagnetic photon. These photons always have precise values, forming the hydrogen emission spectrum.</td></tr>
</table>

<table>
<tr><th>Question</th><th>Evidence</th><th>1-4 marks</th><th>5-6 marks</th><th>7-8 marks</th></tr>
<tr><td>FIVE
(a)</td><td>An RMS value is required because AC is a varying quantity.</td><td rowspan="5">Thorough understanding of this application of physics.

OR

Partially correct mathematical solution to the given problems.

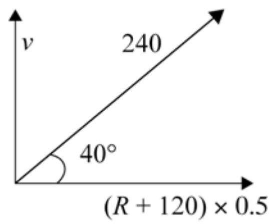
AND / OR

Partial understanding of these applications of physics.</td><td rowspan="5">(Partially) correct mathematical solution to the given problems.

AND / OR

Reasonably thorough understanding of this application of physics.</td><td rowspan="5">Correct mathematical solution to the given problems.

AND

Thorough understanding of this application of physics.</td></tr>
<tr><td>(b)</td><td>AC power is the product of (instantaneous) voltage and current, and is continuously changing. The maximum or peak power is the product of peak voltage and peak current. However this value is the maximum. The average power is half this value. (Reason: the power vs time graph is symmetric and never negative if the current and voltage are in phase.) Therefore RMS power is peak voltage and peak current multiplied together, but to ensure their product (the power) is half the peak power, the current needs to be $\frac{I_{peak}}{\sqrt{2}}$ and the voltage $\frac{V_{peak}}{\sqrt{2}}$ so their product is $\frac{I_{peak}V_{peak}}{2}$.</td></tr>
<tr><td>(c)(i)</td><td>

$(R + 120) \times 0.5 = 240\cos 40$
$R_{tot} = 367.7\ \Omega$
So $R = 247.7\ \Omega = 250\ \Omega$</td></tr>
<tr><td>(c)(ii)</td><td>RMS power supplied = $240 \times 0.5 = 120$ W
Total power dissipated by the motor's resistance and the load resistor is given by I_2 $(120 + r)$
$= (247.7 + 120) \times 0.5^2 = 91.9$ W
The difference in the power supplied and power dissipated is stored in the inductor and then returned to the supplier.</td></tr>
<tr><td>(d)</td><td>Add a suitable capacitor to bring the circuit into resonance.</td></tr>
</table>

Question SIX	Type 1 (explanatory) or Type 2 (problem)	B Evidence	A Evidence
6(i)	2	$R = \frac{V}{I} = \frac{0.2}{0.40} = 0.5\,\Omega$ Straight line, with gradient representing R = 0.5 Ω, passing through (0,0), (0.2,0.4) should be drawn on the graph.	
(ii)	2		Candidates need to refer to the back emf suggested in the theory to **explain** the results. Key points: • The induced emf would oppose the motion of the coil, making it harder to turn. • The voltage supply would need to produce a larger voltage to overcome the induced emf whilst turning the coil. This is why a smaller than expected current is measured for a given applied voltage. No credit given for an explanation based on a change in the resistance of the wire. (The resistance would need to increase from 0.5 Ω to approx 40 Ω, which is unrealistic even with some heating of the wire.)
(iii)	1		Key points: • Faraday's Law states that the magnitude of an induced emf is determined by the rate of change of flux. **For the motor the induced emf should be proportional to the rotation rate.** (Rotation rate is proportional to the rate of change of flux). • The induced emf can be calculated from the difference between the measured voltage and the expected voltage in the wire when it's not rotating. (ie

<table>
<tr><th>Question</th><th>Type 1 (explanatory) or Type 2 (problem)</th><th>B Evidence</th><th>A Evidence</th></tr>
<tr><td></td><td></td><td></td><td>– the difference between the two lines on the graph).

Students must:
• Calculate the back emf (back emf = $V - I \times 0.5$), or determine this emf from the distance between the two lines on their previous graph.
• Plot the back emf against rotation rate (labelled axes, sensible scales, points correctly plotted and straight line of best fit).

Back EMF | Rotation Rate
0 | 0
0.74 | 9
1.22 | 15
1.71 | 15
2.205 | 27
2.7 | 34</td></tr>
<tr><td>(iv)</td><td>1</td><td>Conclusion should include the following:
• A summary of the findings – eg Voltage is non-linearly related to current. The back emf is proportional to rotation rate.
• Reference to the hypothesis – eg the motor generates a back emf proportional to the rate of change of flux as suggested in the hypothesis.</td><td></td></tr>
</table>

Question	Type 1 (explanatory) or Type 2 (problem)	B Evidence	A Evidence
Back emf